



University of Colorado at Boulder

Department of Civil, Environmental, and Architectural Engineering

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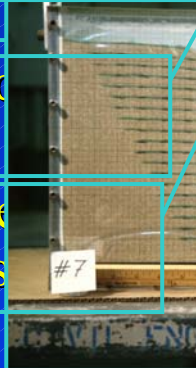
Role of Centrifuge Modeling in the Design of an Evapotranspirative Cover for a Hazardous Waste Landfill

by

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Purposes of Centrifuge Modeling

- Investigation of mechanisms
- Validation of tools
- Reproducing process response
- Expediting some physical processes



Motivation for Centrifuge Modeling of Unsaturated Flow

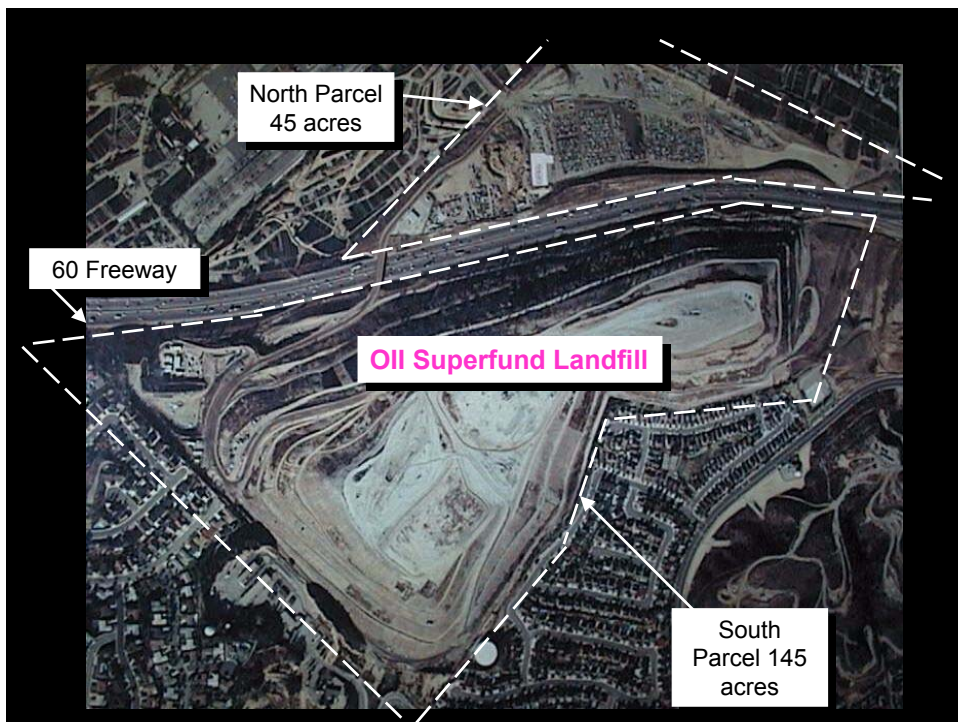
- Favors a systematic control of variables
- Facilitates data collection for validation of unsaturated flow numerical simulations
- Allows critical combination of weather and soil conditions
- Allows prediction of long-term infiltration response in a reduced time frame
- Allows before-the-event, Class A numerical simulations of infiltration problems

OII Superfund Landfill



Oil Superfund Landfill

- 190 acres site in southern California.
- Closure under the USEPA Superfund program
- Intermediate slopes between benches up to 100 ft high
- North Slopes as steep as 1.3H:1V
- South Slopes stabilized with a reinforced toe buttress
- Thickness of existing cover soil ranges from 1 to 15 ft
- Exposed to the high seismic activity of the Los Angeles area





OII Superfund Landfill

- Site was originally a sand and gravel quarry
- 1948 Waste disposal initiated
- 1954 Disposal of liquids in native soil
- 1964 California buys 28 acres for Pomona Freeway (170,000 cu yards of waste in ROW)
- 1976 300,000,000 gallons liquid waste permitted
- 1978 Gas control initiated. Daily cover required
- 1983 Liquid disposal ceased
- 1984 Waste disposal ceased
- 1997 Final cover design completed
- 2000 Construction of cover system completed

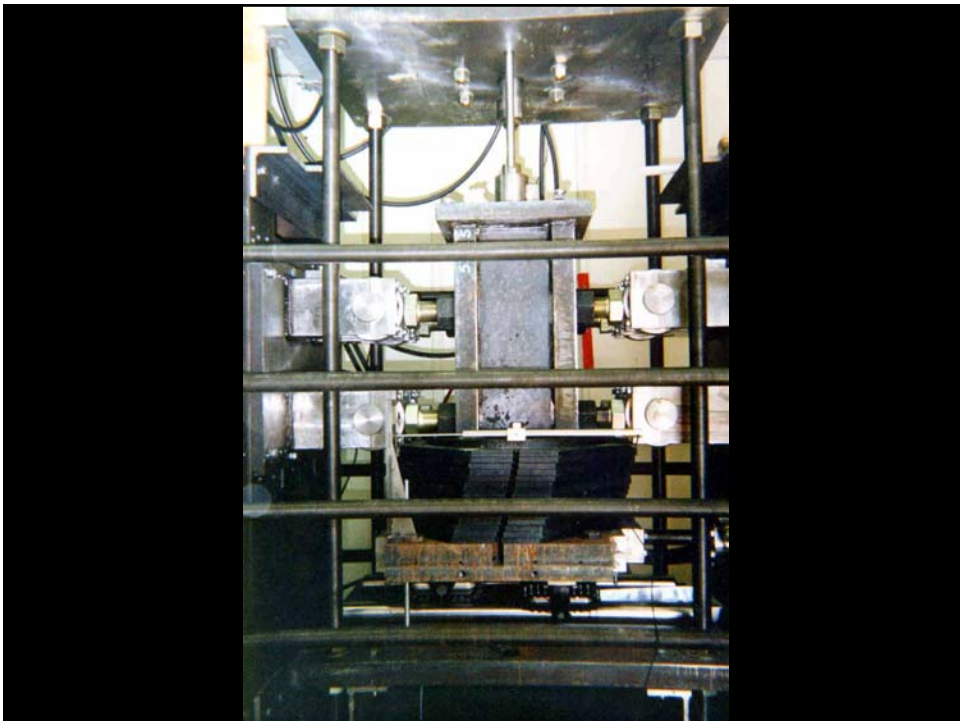
OII Superfund Landfill

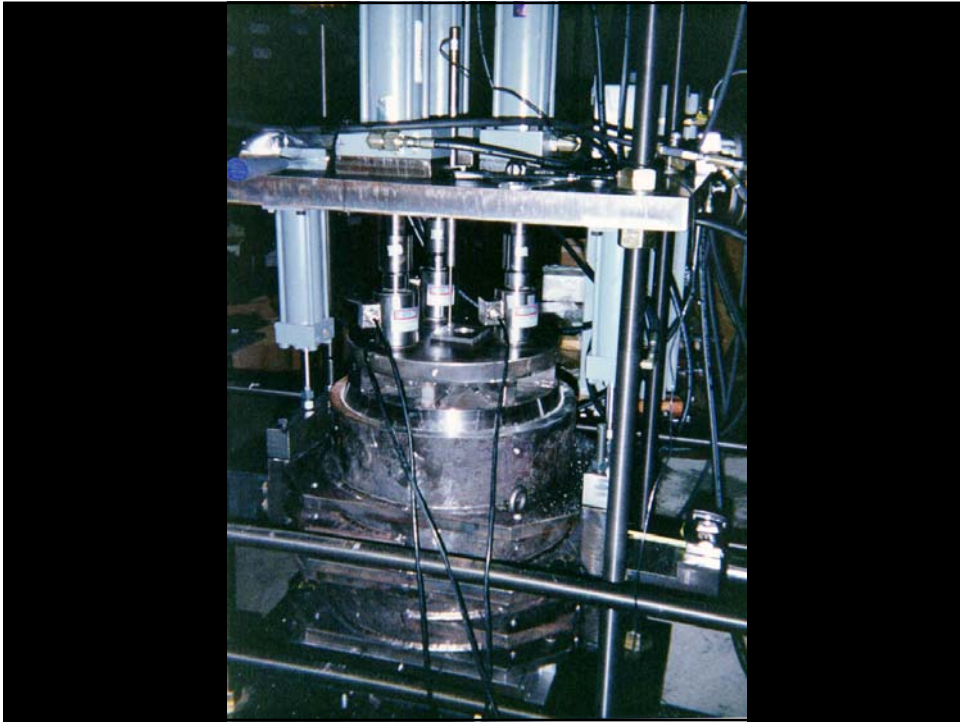
Factors considered in the cover selection and design:

- Percolation
- Stability
- Constructibility
- Refuse deformation response
- Erosion control
- Gas migration control









The diagram illustrates a control volume on a slope. A rectangular control volume is defined by a vertical cover and a sloped bottom. The cover has a height H and a horizontal width $t.H$. The bottom of the control volume is a sloped surface with a vertical height H and a horizontal width t . The control volume is subjected to several forces: a weight W acting vertically downwards, a normal force N acting perpendicular to the sloped bottom, a shear force S acting parallel to the sloped bottom, and a tension T acting along the sloped bottom. The angle between the vertical and the sloped bottom is β . The distance from the bottom of the control volume to the point of application of the tension T is z . The diagram also shows a 'Refuse' pile at the bottom left, represented by a brown bag and some bottles.

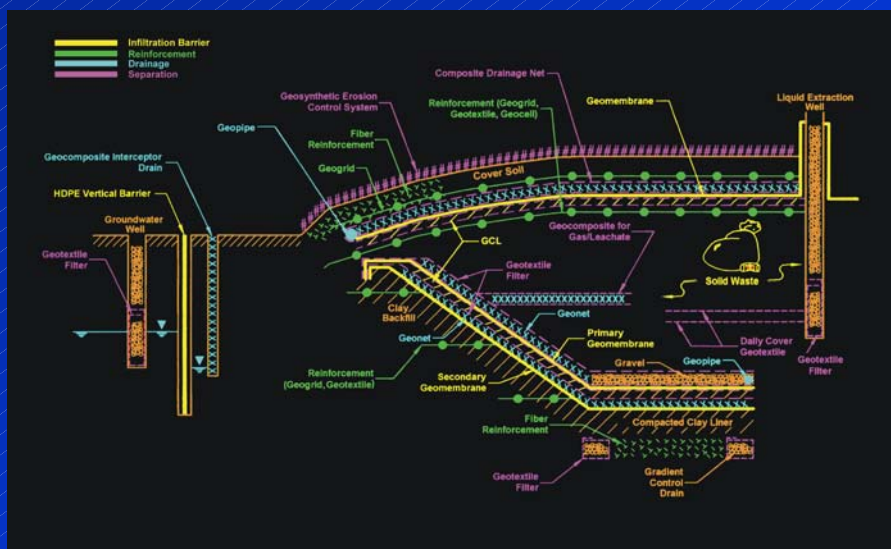
The diagram illustrates a trench in a refuse pile with the following components and dimensions:

- Final Grade**: The top surface of the refuse pile.
- Reinforcements**: Horizontal lines within the refuse pile, likely representing layers of material or structural supports.
- ET cover**: A layer of material covering the trench.
- Trench into Refuse**: The main excavation in the refuse pile.
- Top of Refuse**: The upper edge of the refuse pile.
- Refuse**: The material being excavated.
- Dimensions**:
 - Varies**: A dimension that changes along the length of the trench.
 - 6' (min)**: Minimum length of the trench.
 - 5' (max)**: Maximum width of the trench.
 - 2' - 3'**: Width of the trench at the bottom.
 - 2' (min)**: Minimum width of the trench at the bottom.
 - 45°**: Angle of the trench walls.

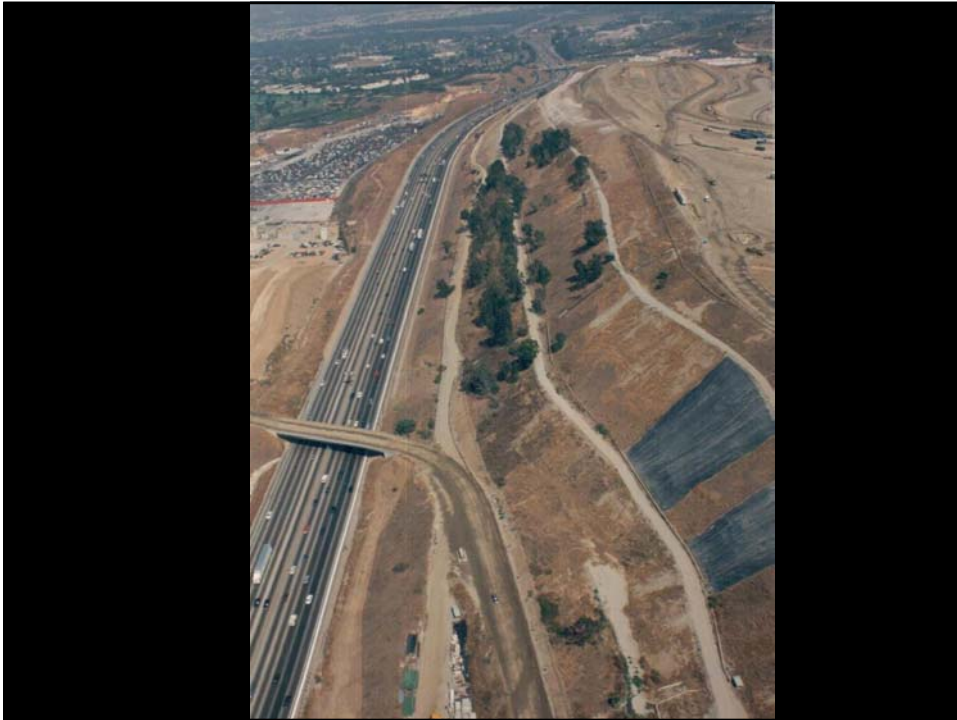
Source: Zornberg et al. 2001

**OII is the first
Superfund site with
an EPA-approved
Evapotranspirative
cover.**

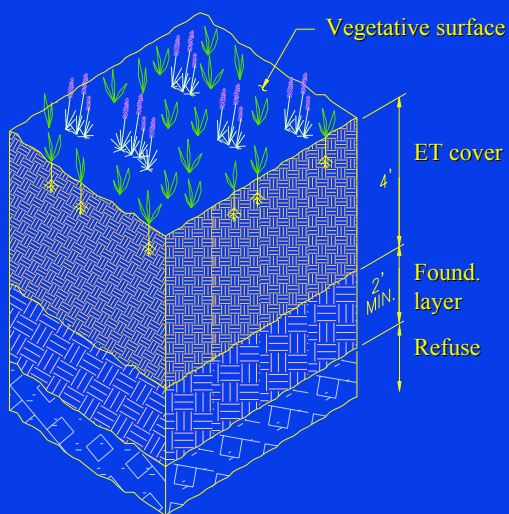
**What does a Modern Landfill Look
Like?**



Source: Zornberg and Christopher 1998



What does an ET cover look like?



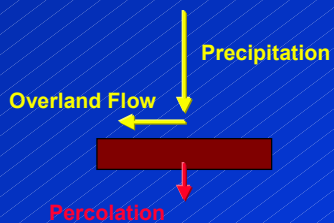
An ET cover:

- Controls percolation
- Is stable under static and seismic conditions
- Controls erosion
- Is aesthetically pleasing
- Is easy to maintain
- Is cost-effective

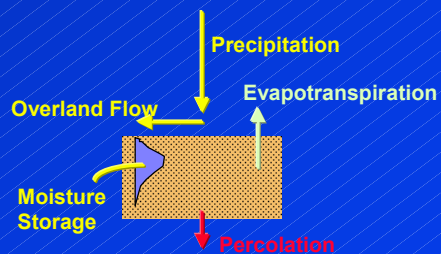


Alternative Cover Systems for Arid Climates

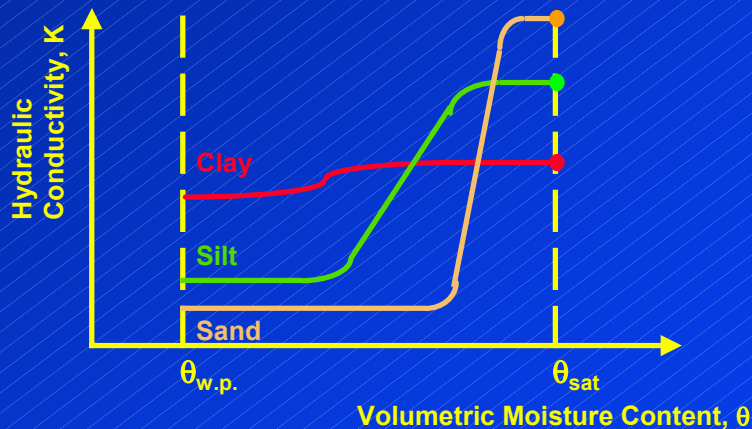
Prescriptive Cover ("Barrier" System)



ET cover ("Reservoir" System)



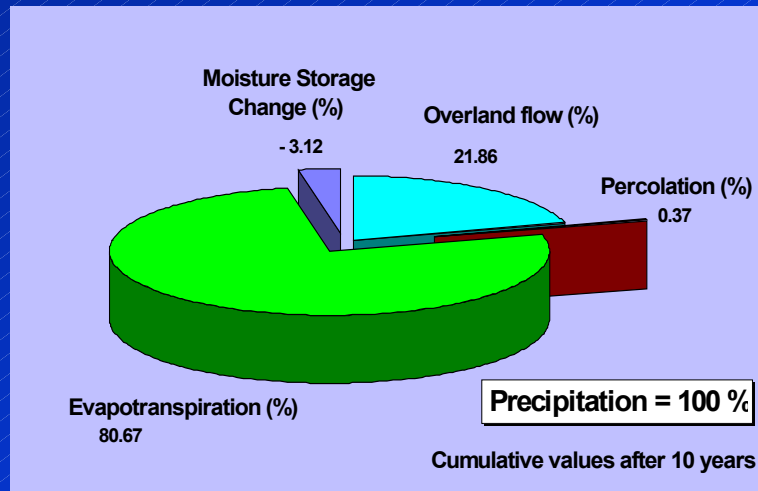
What are the Hydraulic Properties of the ET cover Material?



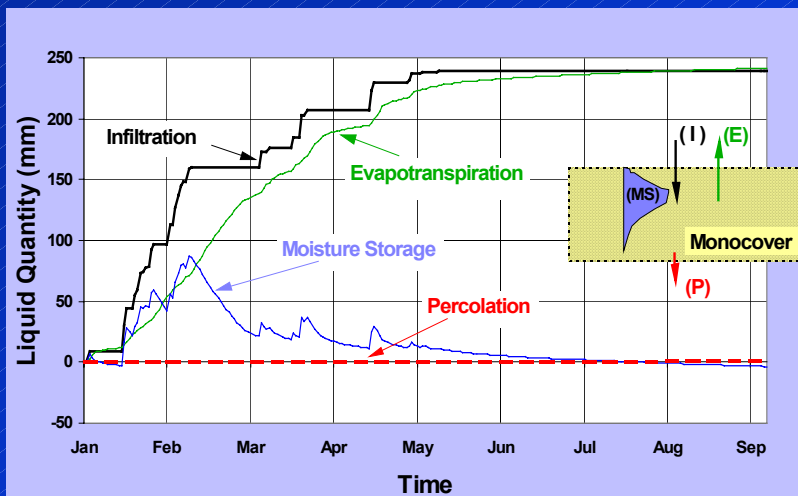
Phases in the Study

- Evaluation of the performance of a Baseline ET cover
- Equivalence demonstration of generic cover
- Sensitivity evaluation of parameters governing the ET cover design
- Design
- Equivalence demonstration using soil-specific hydraulic properties

What is the ET cover Water Balance?

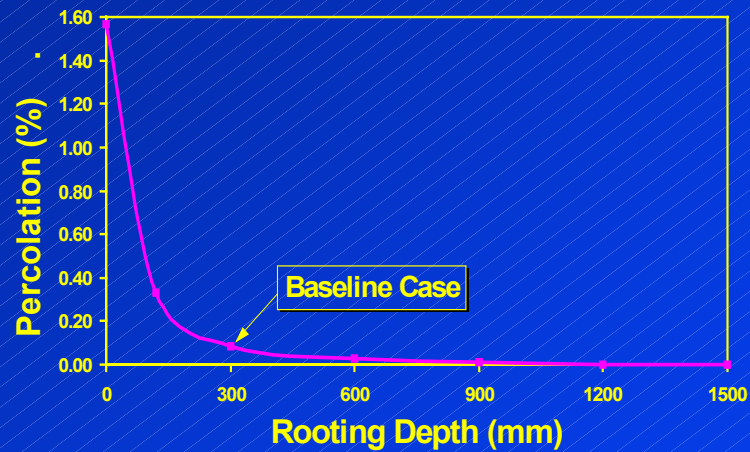


How does the ET cover Perform in a Wet Year?

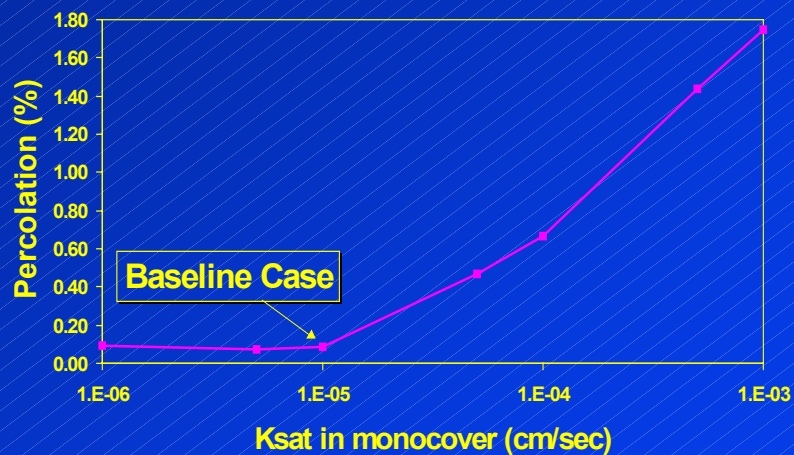


Source: Zornberg et al. 2003

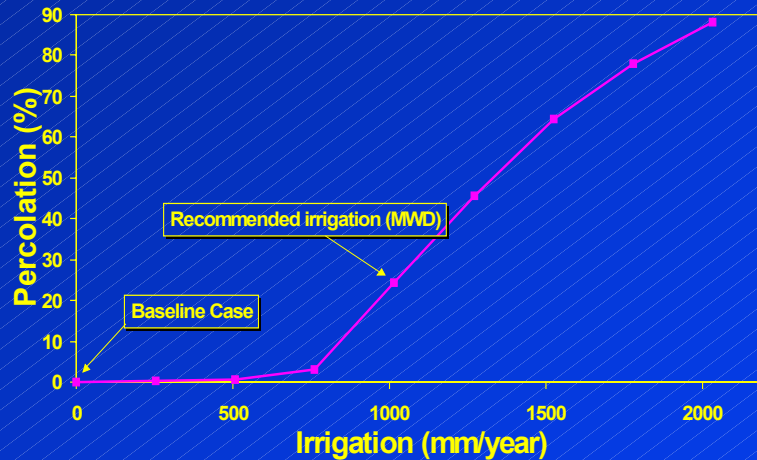
Parametric Evaluation: Rooting Depth



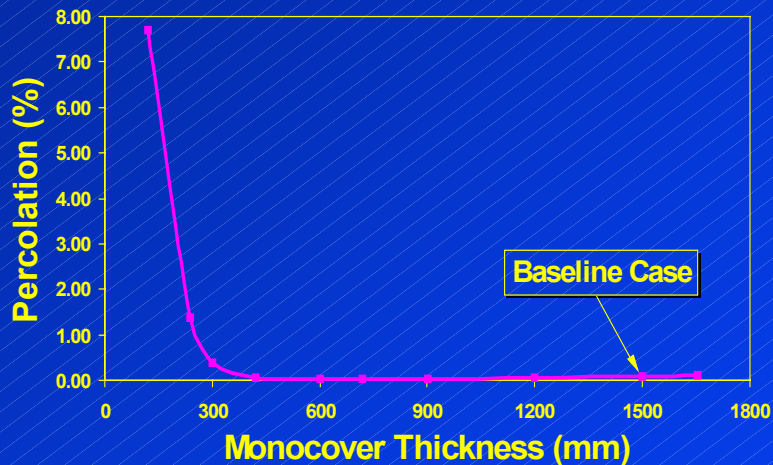
Parametric Evaluation: K_{sat}



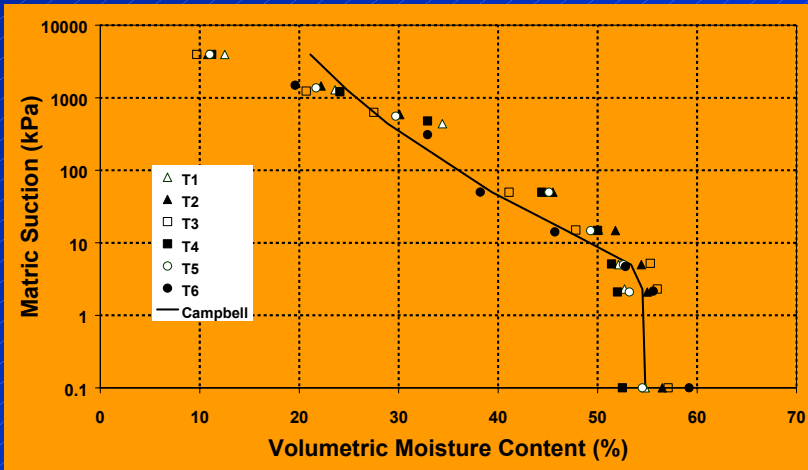
Parametric Evaluation: Irrigation



Parametric Evaluation: Cover Thickness

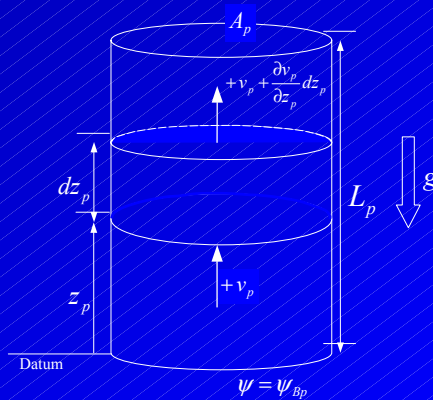


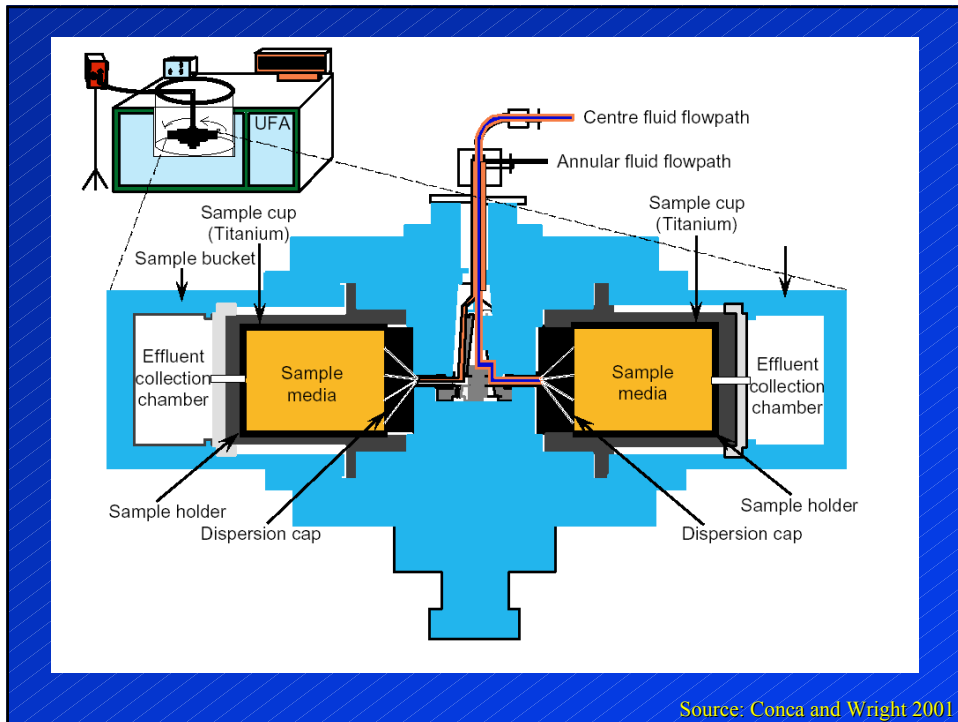
Use of soil specific properties (Characteristic curves)



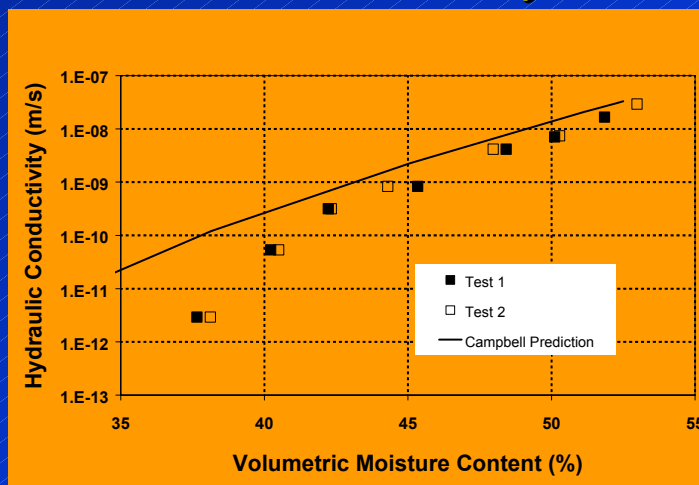
Source: Zornberg et al. 2003

Control Volume in a Prototype (1g level)



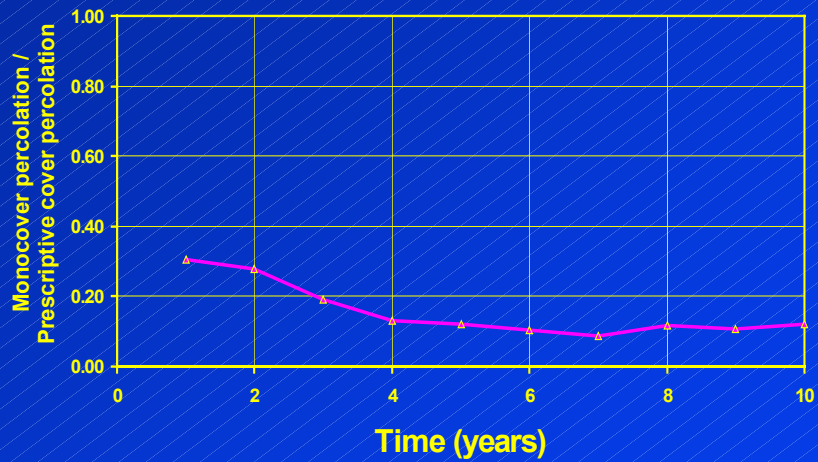


Unsaturated Hydraulic Conductivity



Source: Zornberg et al. 2003

Equivalence Demonstration





Conclusions

- An ET cover design is feasible for a wide range of conditions (in southern California!)
- There is a rooting depth value beyond which percolation does not decrease significantly
- There is a cover thickness beyond which percolation does not decrease significantly
- A 1500 mm-thick ET cover with 300 mm rooting depth outperforms a prescriptive cover system
- Centrifuge modeling allowed characterization of the unsaturated properties of the engineered cover soils

Evapotranspirative Cover System for a Hazardous Waste Landfill

The design of the closure system for the OII Superfund Landfill is a good example of a project in which numerical modeling and centrifuge testing contributed to provide a safe, technically sound, and cost-effective solution.

